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ABSTRACT

This paper describes the research and development (R & D) strategy employed in a major chemical manufacturing corporation and compares the strategy to that which is generally used in educational R & D efforts. The paper underscores development practices in the chemical industry as they relate to devleopment activities in education. Some of the basic implications for improvement of educational R & D derived from the comparison include (1) the effects of management and organization on the development process, (2) the increased applicability of basic research efforts through a greater communication between developers and researchers, (3) the importance of market research for new product ideas and evaluation, and (4) the utility of independent quality control and tests for side effects to improve educational products. (Author)

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RESEARCH AND DEVELOPMENT AND THE CHEMICAL INDUSTRY: IMPLICATIONS FOR EDUCATION

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RESEARCH AND DEVELOPMENT AND THE CHEMICAL INDUSTRY: IMPLICATIONS FOR EDUCATION

This paper describes the research and development (R and D) strategy employed in a major chemical manufacturing corporation and compares the strategy to that which is generally used in educational R and D efforts. In particular, the paper will underscore development practices in the chemical industry which may have implications for development activities in education. Information on the chemical R and D strategy was obtained through interviews with personnel at a nationally known manufacturing corporation that specializes in the development and production of chemical cleaning products such as laundry detergent. The main retailer of these is the grocery store; the target consumer is the "housewife."

Organizational structure of the corporation

The corporation studied for this paper is comprised of five major departments: sales, marketing, applied research and development, quality control, and manufacturing. The research groups consist of teams of people who have a chemical and/or engineering degree, led by a person of greater seniority -- or expertise -- in the product area (e.g., bleach). The research staff tend to specialize in one of the three types of products produced in this section of the corporation: bleaches, soaps, and softeners.

In general, personnel in the corporation rely on on-the-job training for specialized knowledge and skills. Though the corporation does provide management courses for those staff members in management positions, interviewed staff members felt that such courses served more to "polish up natural

ability than to actually promote good management skills. Further, no interns or research assistants similar to those in academia are employed, although some of the staff interviewed thought this might be a good idea for the company to try. There is a fairly low rate of attrition of personnel, attributable to current economic and employment problems as well as to the nature of the corporation and the educational requirements for the staff.

The studied corporation appears to have a relatively informal atmosphere compared to some of the mega-corporations with which it competes. This type of atmosphere has advantages and disadvantages, the most serious being that communication both horizontally and vertically in the organization is considered poor. This was attributed to "job protection" and a common reliance on verbal rather than more time-consuming, but explicit, written communication.

The R and D strategy

Both in education and the chemical industry, the research and development functions include: basic research, applied research, development, production, dissemination, and adoption. These functions often are referred to as if they occurred in a linear sequence, yet actual practice in the chemical industry -- and in education -- involves both formal and informal feedback loops, making many R and D efforts more iterative than linear. Educational and chemical R and D also are similar in that these functions may be carried out within a single organization or may be divided among smaller, more specialized organizations. The corporation studied for this paper performs all of the R and D functions listed above, except basic research. For this function, the corporation relies on huge corporations that deal in raw chemicals and materials.

In this particular chemical corporation, development of new products consists of five major steps, similar to those commonly employed in educational development: 1) product selection; 2) product specification; 3) specification of outcome measures; 4) development of product prototype, and; 5) market testing and evaluation, which is followed by revision or full-scale marketing.

The remainder of this paper will consider each of these phases of development and discuss implications for development strategies in education.

New product development

Product ideas in the chemical industry are derived from several sources. Approximately 80% of them come from the established market with an emphasis on how to "get a piece of it." In this case the objective may be operationalized as "to develop a product like Brand X." The remaining 20% of new product ideas come from three sources, one of which is feedback from sales and market research, often in the form of consumer interviews, letters and buying patterns. For example, polyester clothing retains greasy soil, so when polyester clothes became popular consumers requested detergents that would effectively clean this new type of fiber. Other new product ideas may be spinoffs generated during applied research on other products. Still more ideas come from innovations arising in basic research done both in-house and in the laboratories of the large companies who supply raw materials. An example of this is when a large supplier discovered a softening treatment for a fiber and suggested that a manufacturing company might be able to use this knowledge to develop a product for which the supplier would provide the needed raw materials.

Education might profit from the example of the chemical industry in

in product selection in several ways. If educational product development becomes the kind of operation that is forced to support itself by relying solely on the profits from its products, it may well emulate the chemical industry in expending most of its energy trying to compete for the available market. The outcome of such a strategy would depend, for example, on the competency and conscientiousness of the competition, and the degree of change needed in the market. Obviously, development based on a competitive marketplace might not benefit the consumer.

Educational developers might be better able to gather and utilize knowledge from basic research if there were an analog to the market - motive of the basic researchers in the chemical industry, who suggest ideas to developers and are "rewarded" with a market for their raw materials.

Education, like industry, must be concerned with feedback from consumers. Industry's motivation is increased profits. Educational R and D's motivation is to meet the needs of the users. Such needs typically are defined by user perceptions of need as well as the judgments of developers and researchers. An interdependent working relationship among researchers, developers and users could more closely align these two definitions of "need."

Product specification in the chemical industry is sometimes the weakest point in the development process, primarily due to the lack of formalized explication of the product's objective. This may occur because the persons (or groups) responsible for setting the objective do not, themselves, have a clear, unambiguous notion of what the product is to accomplish.

The lack of a carefully circumscribed objective may not be too serious if, for example, the aim is "to develop a product like Brand X". Often the chemical composition of "Brand X" may be known; the objective is thus relatively

clear to the laboratory developer. In other cases, though, developing a product "to compete with Brand X" may leave the operational definition of the objective entirely up to the development team. A highly competent, creative team may be at its best in such an unfettered situation. However, certain products or certain development organizations cannot afford to rely on this loose strategy and more explicitly defined objectives become necessary. An absence of clarity can result in the development of prototypes that are off-target, which is usually a waste of resources and reduces staff morale.

An important difference between education and the chemical industry in the product specifications stage should be noted at this point. The ultimate effects of new products and programs emanating from educational R and D efforts are often intangible, e.g., increased learning, changed attitudes. Faced with the difficult task of measuring such intangible effects educators often judge the quality of new products and procedures against clearly defined, pre-specified statements of desired product outcomes (i.e., "objectives"). Sets of objectives are thus frequently the only evaluative yardstick available to the educator. This is not necessarily so in the chemical industry. Unlike educational outcomes, the composition of chemical products are usually absolute, finite, and directly measureable. In a simplistic sense, stating the formula of a new product is synonymous with stating its objective.

A second weakness of product specification in the chemical industry is that often little or no explicit reason or supporting information is provided to justify selection of a particular objective. Information relevant to product justification would provide the development team with valuable

information to guide their decisions during the course of prototype development and revision. This information may be lacking because it has never been gathered, for example, if an idea comes from a powerful company executive whose ideas are usually adopted by a development team without further justification or explication. Another reason that supporting reasons and explanations of a proposed product may not reach the development team is poor communication within the company, especially among departments.

Educational developers, too, are susceptible to the problems that can arise when sufficient justification for a new product or program is not supplied. Increasingly, though, educators are turning to the systematic assessment of learner needs to help them identify high priority objectives worthy of receiving instructional time and resources. Such needs assessment data can serve the twin functions of, first, guiding the development process itself and, second, providing baseline information against which subsequent changes in learner behavior can be measured.

The third step in the development process is *determining the measures* to be used in assessing the extent to which the product accomplishes what it is intended to accomplish. The measures used in chemical laboratory tests are usually quite straightforward, objective "X-Y" comparisions. In all but the most unique products, intended outcomes can be specified before the product is actually developed. If the product specifications are vague or fail to identify important aspects of the product, insufficient or inappropriate tests may be used. This problem tends to occur when one section of the corporation is poorly informed (or not informed at all) about decisions previously made by another section of the corporation. An example of this occurs when the Quality Control Department tests product containers for stress

without knowing that the Sales Department intends the product to be stackable in a warehouse, necessitating that the container be capable of withstanding thirty pounds of pressure.

Certain products must meet government regulations, so often standard toxilogical tests are performed by independent laboratories. The laboratories are selected by the corporation on the basis of speed, i.e., which one will facilitate marketing the product as soon as possible. Process engineers then formalize the applied researchers' ideas to suit the company's capabilities. This information, together with data from in-house and independent testing, is disseminated to the Marketing, Manufacturing, and Sales Departments for decisions regarding continued development of the product. The major criteria for these decisions are: Does the product perform equal to or better than the competition? Is it profitable? Is it manufacturable in large quanitities by the corporation? And, is it aesthetically pleasing? The latter question is usually answered on the basis of data collected on previous products.

Several aspects of test-specification in the chemical industry are relevant to educational R and D. Note that quality control (e.g., of toxic side effects as well as other industry standards) is a standard part of every product's development, partially due to government regulation and part to industry competition. Perhaps a catalog of relevant side effects (both positive and negative) for checking educational products, analogous to the skin, eye, and oral toxicity tests done on soap products, may eventually be developed that could bring greater quality control to educational products.

It is also worthwhile to note that testing is done on the entire product, i.e., including the package. This requires a coordinated effort of the various groups who work on a given product, each contributing important information in its area of expertise. Greater input of field testing data from similar previously-developed products seems to help cut down on the number of revisions a new chemical product must undergo. This point underlines again the importance of communication among the groups of researchers, developers, users and others involved in producing and using the product.

The fourth step in product development is the actual creating of the *product prototype* according to the product and test specifications. The general timeline of developing a new product usually requires about three months from the idea stage to solving the problems of how to make it and how to package it. Another three to nine months are then required to fully develop it and get it ready for full market production. In some cases a final product may evolve over a period of years if the criteria it must meet continue to change. For example, a heavy duty detergent may be developed, then revised to a liquid form, then made phosphate-free. In other words, developers prepare a product for field testing by keeping a continual watch on the market. Clearly, there is little profit to be derived from a product intended to meet an outmoded need.

Educational developers are not as fully engaged in the race of changing technology as are their counterparts in the chemical industry. There will, of course, always be children who must learn to read, multiply, explore their values, and so on. The design of educational products, though, might

be improved if educators remained sensitive not only to the expressed needs of teachers and students but also to their actions. For example, what products are school districts actually purchasing? How are teachers actually using successful products? Will a new product be compatible with hardware systems currently in use in schools?

After a product prototype is developed and tested in the laboratory, the last step in product development at the corporation studied is *test marketing and evaluation of the prototype*. The product is marketed in regional markets first and if data show promise, it is nationally marketed. Some of the major manufacturers use test families, but this has become less cost-efficient and has been discontinued by many companies. The most important criterion in determining whether to put a new product into full-scale production is whether the consumer buys the product after trying it once. Data are collected and analyzed on three entire re-buy cycles. This sales curve is then compared to the expected curve that was determined through complex calculations involving variables related to the competing products, the marketing plan, and the purpose of the product. If the product has gained a profitable market, it is kept. If not, it is dropped unless it appears to be cost-effective to revise it. If this is the case, further data are gathered, usually in conjunction with outside firms that are experts in the field of market research. This effort may entail consumer interviews to determine problems, methods of use, and other positive or negative side effects. Other data may be collected from the retailers to find out if revisions in the marketing plan should be made. Thus, revision suggestions may be made entailing the product's packaging, pricing, place-

ment on the retail shelf, and so forth as well as in the product itself.

It should be noted that this emphasis on financial success regardless of what consumers do with the product after they buy it is different from at least some educational development efforts. However, seldom does the educational developer take such care in researching the market, which may explain why so many educational products fail. Interestingly, of all new chemical products developed, about 20% make it as far as the initial market testing; of those, two-thirds fail in terms of sales. Hence very few new product ideas eventually become successful products. This expected low success rate is not tolerated in education probably because educational R and D is not financially self-sufficient and must rely on various government agencies and foundations for support. They, of course, would rather support success than failure. It is thus in the educational developers' own best interests to strive for a 100% success rate (in terms of completing projects) and to shield failures from public recognition.

In summary, some of the basic implications for improvement of educational R and D to be derived from this examination of a chemical corporation's product development process are as follows:

(1) The organization, management and communication lines of a company directly affect the development process and the quality of the products.

(2) Market research coupled with greater communication between basic researchers and developers may increase the applicability of basic research efforts.

(3) The user is a valuable source of ideas for new products and for data useful in formative evaluation and revision of prototypes.

(4) Independent quality control and standardized tests for side-effects would improve efficiency and effectiveness of educational product development.

As with other business-oriented enterprises, the R and D strategy utilized in the chemical industry is heavily influenced by an emphasis on the marketability of its products. This can mean a concern with the needs and desires of the consumer as expressed in market research, consumer interviews, and the use of test markets. While in business this is for the purpose of maximizing sales, in education it might meet the mission-oriented objective of maximizing the "fit" between educational products and the user's needs or desires.